

Relative Growth of Oaks and Pines in Natural Mixtures on Intermediate to Xeric Piedmont Sites

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ABSTRACT

Increment cores and stem analyses from a growth and yield study in naturally regenerated pine-hardwood stands in the Piedmont were used to compare relative growth of oaks, pines, and other non-oak hardwoods on intermediate to xeric sites in that region. The primary focus in this paper is on the relative growth of only the oak and pine components. The stem analyses show that pines early in stand life grow faster in height than the oaks (a widely observed result), reaching an average maximum height advantage of 20 ft. by an average age of 32 years. Beyond this age, the stem analyses showed annual pine height growth slowing dramatically falling below the rather steady 2 ft. per year observed for the oaks through age 70 thus reducing the average cumulative difference as the stands aged. For example by age 55, the average 20-ft. cumulative height advantage of pine was cut in half to 9.6 ft. We show that oaks attain basal area growth comparable to that of pine as early as age 15, and that beyond age 15, the oak growth advantage increase through stand age 70, outgrowing the pines by 70 percent between ages 60 and 70

INTRODUCTION

Pine-hardwood mixtures are common in the Piedmont physiographic regions of Virginia, North Carolina, South Carolina, and Georgia. Unpublished data from the Forest Inventory and Analysis (FIA) Unit of the Southeastern Forest Experiment Station show that 1/3 of the Piedmont forest—7.1 million of 22 million acres—is in stands where 30 to 90 percent of the total basal area is in hardwood or 10 to 70 percent in pines. Although loblolly pine (*Pinus taeda* L.) is the dominant pine species, other yellow pine species are included in the estimates.

On these intermediate to xeric Piedmont sites, it is well known that pine growth exceeds that of oaks and other hardwoods early in stand life. This dramatic pine growth advantage is why we often hear these areas described as "pine sites." At the same time, oak coppice and advanced regeneration do well on these sites when they are present and are not aggressively controlled during site preparation. Oaks also outlive pines on these dry sites. Barring major disturbance, therefore, the oak component normally increases as stands on these sites age. In fact, it is common on eroded Piedmont sites for mortality of dominant and codominant pines to begin as early as age 40, thus speeding the composition toward oaks. Jones (1991) in his research on landscape ecosystem classification found oaks abundant in late-successional stands he studied in the Piedmont. He also found that the oak

species associations were indicators of a site-quality gradient. In summary, oaks regenerate naturally and persist on these sites. Their survival is site-specific, but they can generally be thought of as well-adapted to these sites.

Given this suitability of oaks for these sites, it is logical to ask how well they grow in long rotations relative to pines and non-oak hardwoods. Relative growth dynamics of the pine, oak, and non-oak species groups have not been examined for sawtimber rotations of naturally regenerated mixtures of pines and hardwoods. One objective of a major study we are installing, and the major focus of this paper, is to examine these growth dynamics.

METHODS

A growth and yield study in naturally regenerated mixtures of hardwood and pine has been initiated to study growth dynamics (Lloyd 1991). Fifty circular, 1/5-acre permanent plots measured in the first phase of this study form the dataset for this paper. Sampled stands contained from 93 to 182 sq. ft. of basal area per acre in merchantable and unmerchantable trees, and stand ages ranged from 20 to 79 years. Twenty one plots are on the Piedmont Ranger Districts of the Sumter National Forest and 29 are on the Clemson University Experimental Forest.

Diameters at breast height were measured on all trees, and merchantable sized trees (4.6+ in.) were tagged and mapped by azimuth and distance from plot center. Separate samples of hardwood and pine trees covering the diameter range on each plot were selected for measurement of total height. Although growth and mortality ultimately will be estimated by remeasuring these plots, recent growth was calculated from increment cores taken from merchantable-sized trees. Radial growth for the last 5 and 10 years was measured with a Bannister incremental measuring instrument. Radial growth data were used to estimate basal area of trees 5 and 10 years prior to plot establishment. Only survivor growth can be studied in this way.

Ten-year basal area growth of surviving trees was estimated as the difference between basal area of merchantable trees at measurement time and the calculated basal area of the same trees 10 years earlier. It was divided into components for pines, oaks, and non-oak hardwoods, and separate prediction models were developed for each species component. The same model form was fit to all groups. The predictor variables screened for these models were: (1) initial merchantable basal area in the given species group, (2) the species group's basal area as a proportion (ratio) of the total merchantable basal area, (3) the reciprocal of stand age, and (4) the cross-products of (1), (2), and (3).

Cumulative height growth differences were examined next. It has been widely observed that early height patterns favor pine. The goal here was to examine cumulative height over a longer time period. These height data were obtained by analyzing stems of pairs of one dominant or codominant oak and one such pine located near (not in) each permanent plot. Thus, two height/age curves were plotted for each plot. Each potential stem analysis tree was cored prior to felling to determine age and to seek evidence of previous suppression of growth. Trees with previous suppression were excluded. Substitutes were examined in the same way until a free-to-grow tree was found. Finding suitable trees was not difficult; we rarely had to go beyond the first choice. The resulting cumulative height/age

curves were used to examine height-over-age patterns. In order to assess long patterns, the cumulative height data set was screened to include only plots in stands over 54 years old. Twenty plots (40 trees) met this criterion.

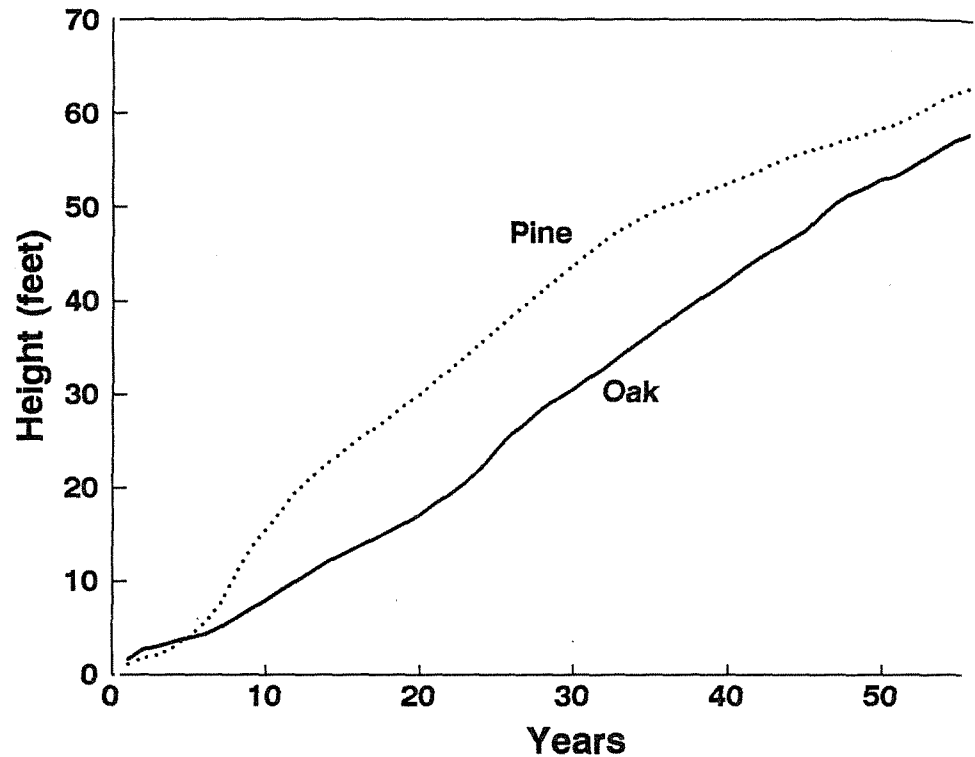


Figure 1—An example of a typical cumulative height pattern observed in stem-pairs of oaks and pines located near each of 50 permanent growth and yield plots in naturally regenerated hardwood and pine mixtures in the Piedmont physiographic region. The sample pine was always a loblolly, and the oak could be a dominant or codominant of good form from any of the oak species found on these sites.

The first step was to examine graphs of the height/age data for the pairs of oaks and pines on each plot. Figure 1 illustrates the predominant pattern observed on all plots. Because we estimated height at the end of every growing season by interpolation, it was easy to compute the height difference between oaks and pines over the life of the stand. Since pines were generally taller, we first subtracted oak height from pine height, and then fit to each of the 20 data sets a simple quadratic polynomial expression

$$H_d = c_0 + c_1t + c_2t^2 \quad (1)$$

where H_d is the difference in cumulative height between the pine and oak at each age (t). We then used the estimates of c_0 , c_1 , and c_2 and the calculated extreme values to estimate for each of the 20 plots the age at which the difference between pine and oak height was maximum and what the maximum difference was at that time in stand life.

The final analytical procedure looked at the average shape of the oak cumulative height pattern. All height/age data for the 20 sampled oaks were pooled into a single data set, and then the model

$$h_0 = e^{at^b} \quad (2)$$

was fit using nonlinear least squares. The variable h_0 is cumulative oak height at age t , and a and b are the model parameters to be estimated.

RESULTS

The model used to predict 10-year pine basal area growth (b_p) is

$$b_p = g_0 + g_1 B_p + g_2 P_p + g_3 B_p/t \quad (3)$$

where B_p is the initial basal area of presently surviving pines as it occurred 10 years prior to plot installation, P_p is the proportion of total initial merchantable basal area (B) represented by pines (that is, $P_p = B_p/B$), and t is initial stand age. There are similar models for oaks (b_o) and non-oak hardwoods (b_N), where

$$b_o = g_0 + g_1 B_o + g_2 P_o + g_3 B_o/t \quad (4)$$

and

$$b_N = g_0 + g_1 B_N + g_2 P_N + g_3 B_N/t. \quad (5)$$

To further illustrate the definitions of the independent variables, the following relationships hold across the three models:

$$B_p + B_o + B_N = B \quad (6)$$

and

$$P_p + P_o + P_N = 1. \quad (7)$$

The R^2 statistics of fit for Equations (3), (4), and (5) above are 0.91, 0.75, and 0.77, respectively. R^2 values of 0.8 for regression models of periodic growth are considered good. The corresponding estimates of the model parameters (g_0 , g_1 , g_2 , g_3) are (-3.079134, -0.21006, 32.38342, 6.670954) for pines, (1.879838, -0.0051275, 8.509635, 5.819824) for oaks, and (0.4226926, 0.1848599, -9.917444, 2.909263) for non-oak hardwoods. These estimated parameters were used in the appropriate model to predict components of 10-year growth for selected values of initial stand ages listed in table 1. It is not the goal in table 1 to predict for the actual initial stand conditions, but rather, to compare relative oak and pine growth performance. For this reason, the same set of P -values was used for each initial age, that is, $P_p = 0.4$, $P_o = 0.4$, and $P_N = 0.2$.

Table 1—Predicted periodic (10 years) basal area growth of survivors at four ages in pine-hardwood mixtures which have merchantable basal area composed of 40 percent pine, 40 percent oak, and 20 percent other hardwoods

Species group	----- Initial stand age ¹ -----			
	15	30	45	60
	----- ft. ² /acre/10 years -----			
Pine	17.4	10.3	7.4	5.5
Oak	17.5	12.1	10.3	9.3
Other hHardwood	4.5	3.5	3.4	3.6
Total	39.4	25.9	21.1	18.4

¹ Total merchantable basal area at the beginning of each period was 80 ft.² at age 15, 90 ft.² at age 30, 100 ft.² at age 45, and 110 ft.² at age 60.

These proportions are all within the ranges observed in the data. Fixing the proportions permits direct comparisons because the oak and pine predictor basal area growth come from the same initial basal area.

Table 1 shows that by age 15, the oaks were producing as much basal area growth as the pines for the same initial basal area. As the stands aged, the oaks increasingly outgrew the pines in basal area through age 70. At that time, the oaks were growing 70 percent more per 10-year period than the pines. The footnote to table 1 explains how the corresponding values of initial basal area were calculated. For example, for stand age 30, the observed data averaged about 100 sq. ft. of initial merchantable basal area (that is, B_0). Since P_p and P_o are both set equal to 0.4, the initial basal area components were 40 sq. ft. for both the oaks and pines. Thus, table 1 shows that for initial stand age 30, the 40 sq. ft. of oak grew 40 sq. ft. of basal area in the next 10 years (that is, from age 30 to age 40), while the 40 sq. ft. of pine basal area grew 10.3 sq. ft. in the same period. This growth advantage of the oaks increased with increasing initial stand age.

Figure 1 illustrates how pines on these Piedmont sites outgrow oaks. Using Equation 1, we found that the average stand age of maximum pine/oak height difference was 32 years, and the average height difference at that point was 17 ft., with a quartile range of 17 to 22 ft. However, by stand age 55, the average pine/oak cumulative height difference was cut in half, to 9.6 ft. The pattern of growth suggests that pine height growth slows dramatically after age 30 and steady oak height growth continues generally across plots. It should be kept in mind that our working definition of pine-hardwood mixtures is not a closed pine overstory with a hardwood undergrowth. We only work with stands in which the pine component is sparse enough to allow some light from above for the largest hardwood, even though they are shorter than the pines.

Visual examination of the pooled oak height data suggested a steady growth trend through stand age 70. We examined this average trend by fitting Equation 1 to the cumulative height data for the 20 plots that were 55+ years old. The nonlinear least squares estimates of the model parameters were 0.71 and 0.98 for a and b , respectively, and the value of e^a was 2.03. Since b was nearly equal to 1, the analysis suggests a rather steady 2 ft. of height growth per year. This average growth rate was suggested independently in another study (Geisinger and others 1989) of pine and hardwood regeneration. Table 2 shows oak height growth of 3.5 a

Table 2—Average heights of five species groups after four growing seasons following the winter-fell, no-burn treatment of the pine-hardwood regeneration study.

Growing season	Pine	Oak	Hickory	Blackgum	Other hardwood
----- ft. -----					
1988	1.0 ¹	3.5	1.7	2.8	4.0
1989	1.5	6.9	3.8	5.0	7.3
1990	3.3	8.9	5.2	5.9	9.1
1991	7.5	11.1	7.0	7.4	11.2

¹ Average height of seedlings planted in the 1988-1989 growing season.

ft. per year during the first two growing seasons, followed by a slowing to around 2 ft. per year the third and fourth growing seasons. Table 2 also reinforces the pine height growth pattern of lagging for around 3 years, and then dramatically accelerating. In this case, the pine grew 4.2 ft. in the fourth growing season.

CONCLUSIONS

As stated numerous times in this symposium, getting oak regeneration on xeric to intermediate sites is not hard when oak root stocks and advanced reproduction are present in clearcut stands. The data re-emphasize that after a growth lag, pines on these sites clearly outgrow oaks early in stand development. However, a longer-term look at height development tells a different story. It shows how pine growth slows dramatically after age 30, with oak rapidly cutting the height deficit. Although we do not have basal area growth data for very young mixed stands, this analysis shows oak basal area growth equaling that of pine by age 15. From that point, oak basal area growth increasingly surpasses the pines, reaching a 70-percent advantage between ages 60 and 70.

Given the increasingly important values of oaks for aesthetics and wildlife, the increasing stumpage prices for high-quality oaks, and the growing markets for low-grade oaks, managers of relatively dry upland Piedmont sites should take a close look at our results. We know that oaks are ecologically suited for these sites because they regenerate and live long lives there. Their growth performance in relation to pines is not impressive early in life, but our data indicate that they catch up later. Thus, they would appear to be sensible choices for sawtimber rotations.

LITERATURE CITED

- Geisinger, Donn R.; Waldrop, Thomas A.; Haymond, Jacqueline L.; Van Lear, David H. 1989. Sprout growth following winter and spring felling with and without summer broadcast burning. In: Waldrop, Thomas A., ed. *Proceedings of Pine-Hardwood Mixtures: A Symposium on Management and Ecology of the Type*; 1989 April 18-19; Atlanta, GA: 91-94. Gen. Tech. Rep. SE-58. Asheville, NC: Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 271 pp.
- Jones, Steven M. 1991. Landscape ecosystem classification for South Carolina. In: Mengel, Dennis L.; Tew, D. Thompson, eds., *Proceedings: Ecological Land Classification: Applications to Identify the Productive Potential of Southern Forests*; 1991 January 7-9; Charlotte, NC: 59-68. Gen. Tech. Rep. SE-68. Asheville, NC: Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 149 pp.
- Lloyd, F. Thomas. 1991. Forecasting growth of pine-hardwood mixtures from their ecological land class. In: Mengel, Dennis L.; Tew, D. Thompson, eds., *Proceedings: Ecological Land Classification: Applications to Identify the Productive Potential of Southern Forests*; 1991 January 7-9; Charlotte, NC: 93-95. Gen. Tech. Rep. SE-68. Asheville, NC: Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 149 pp.

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